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Abstract: We review the physics of slow and fast light based on coherent population oscillations in active semiconductor waveguides. Exploiting these effects, microwave phase shifters realizing 360 degree phase shift and operating at tens of GHz have been realized.
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1. Summary

Coherent wave mixing effects in nonlinear media provide the possibility of changing the amplitude and phase of the frequency components of an optical signal. In particular, the process of coherent population oscillations (CPO for short) was demonstrated to enable the control of the group velocity of light, thus realizing slow-light propagation [1]. It is well-known that four-wave mixing effects mediated by carrier density pulsations in active semiconductor waveguides can be very strong and it is therefore natural to seek to exploit these effects to control the speed of light in a very compact and electrically controllable device. For many applications within microwave photonics it is rather the control of the phase shift of the microwave-modulated envelope of the optical signal that is of interest and recent progress within the field has allowed the realization of a 360 degrees phase shift at microwave frequencies of several tens of GHz [2]

In this paper we review the physics of slow and fast light effects in semiconductor active waveguides [3] as well as recent progress towards the application of these effects within microwave photonics [4]. In particular, we introduce and explain the use of optical filtering [5] to increase the magnitude of the phase shift and the microwave frequency at which it can be realized. For practical applications, the signal to noise ratio is important and we discuss the trade-offs at play here [6].

Finally we discuss the possibility of enhancing CPO mediated phase shifts by exploiting the additional effect of structural slow light in active photonic crystal waveguides.

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4. References

[1] M. S. Bigelow, N. N. Lepeshkin and R. W. Boyd, Phys. Rev. Lett., Vol. 90, 113903 (2003).
[2] W. Xue, S. Sales, J. Capmany, and J. Mørk, Opt. Express , Vol. 18, 6156 (2010).
[3] J. Mørk, F. Öhman, M. van der Poel, Y. Chen, P. Lunnemann, and K. Yvind, Laser & Photon. Rev., Vol. 3, 30 (2009).
[4] M. Santagiustina et al., IEEE Photon. Soc. Newsletter, 5-12 (Feb. 2012).
[5] Y. Chen, W. Xue, F. Öhman, and J. Mørk, J. Lightwave Technology, Vol. 26, 3734 (2008).
[6] S. Ó Dúill, E. Shumakher, and G. Eisenstein, J. Lightwave Technol., Vol. 28, 791 (2010).